

Remarks

Claims 28-31, 36-42, 50, 51, 55, 57-62, 66, 68-71, 73-82 and 84-93 are pending in the application. The remaining claims have been canceled.

Claims 28, 36, 40 and 60 are amended herein to specify that the inhibitor is a mercapto-substituted nitrogen containing heterocyclic compound, which is supported in the previously pending claims and the specification as originally filed. In addition, the amendment of claims 36 and 60 address the antecedent basis objection.

Claims 56, 67, 72 and 83 have been cancelled in accordance with the amendment of the independent claims.

Claims 55, 66, 73 and 82 have been amended to specify certain of the claimed mercapto-substituted nitrogen containing heterocyclic compounds. This amendment effectively renders moot the objections to these claims set forth in the Office action.

The Examiner noted in the Office action that the Exhibit A to Mr. Joshi's Declaration was missing. That Exhibit is submitted herewith for completeness, although a copy was provided to the Examiner during the personal interview.

Applicants respectfully request reconsideration of the claims of the present application based on the foregoing amendments and the following points.

Claim Objections

In the Office action, objection was made to the claims on several bases, which have been addressed as noted above. Accordingly, Applicants respectfully request withdrawal of these objections.

Rejections of Claims

Applicants respectfully submit that the present amendment of the claims renders moot all of the rejections set forth in the Office action to which this paper is responsive, except the rejections over combinations specifically relying upon the disclosure of McCoy, US 4356067. Accordingly, Applicants direct the following comments to the McCoy reference.

In the Office action, the Examiner contended that "McCoy teaches that a known brightener for use in a zinc plating solution is 2-mercaptobenzimidazole. Column 2, lines 1-10 and column 7, lines 30-40." The Examiner then concluded without further

analysis that it would have been obvious to use a brightener such as that disclosed by McCoy in the plating process of Heiman in view of Eckles, merely because "McCoy teaches a known brightener for zinc plating" and similarly concluded without further analysis that it would have been obvious to use a brightener such as that disclosed by McCoy in the plating process of Japanese '864 in view of Haydu, merely because "McCoy teaches a known brightener for zinc electroplating".

Applicants respectfully submit that the Examiner has failed to state a *prima facie* case of obviousness of the claimed combination because the disclosure of McCoy relied upon by the Examiner has been lifted from its proper context and, as such, cannot have suggested what is claimed.

First of all, there is nothing at column 2, lines 1-10 of McCoy that relates in any way to the use of any brightener. Applicants do not know to what the Examiner intended to refer.

Second, as has been repeatedly pointed out throughout the prosecution of this application, McCoy (and Eckles and other references cited) relate only to electrodeposition. As pointed out below and in the Declaration of Mr. Joshi, it is well known in the metal treatment and finishing arts that there is a vast difference between the chemistry of immersion plating and that of electrodeposition. The fact that one chemical agent is employed in electroplating provides no suggestion or motivation to the person of skill in the art that the same chemical would have the same or any effect in immersion plating. The fact that the Examiner was able to find a single reference disclosing a single composition that is stated by the reference to be capable of use as both an immersion plating bath and as an electroplating bath provides no sound, factual or scientific basis for the generalization to which the Examiner has attempted to put this disclosure, i.e., that any bath useful for immersion plating can also be used for electroplating and vice-versa. It is Applicants understanding that this is exactly what the Examiner contends, and Applicants respectfully but strongly disagree.

Third, McCoy only teaches the use of mercaptan containing compounds, such as the noted 2-mercaptobenzimidazole, in conjunction with both an organic aldehyde and a trace amount of a metal ion, i.e., in a concentration of 1-15 parts per million. McCoy at no time and in no way suggests the use of the 2-mercaptobenzimidazole alone as a brightener. McCoy at no time and in no way suggests the use of the 2-

mercaptobenzimidazole separate from the aldehyde and the trace amount of metal ion. McCoy in no way suggests the use of this or any other brightener for use in other systems. Only by lifting the 2-mercaptobenzimidazole out of the context of the McCoy teachings can the Examiner possibly contend that this is a brightener that could be used in the process obtained by the asserted combinations of either Heiman and Eckles or Japanese '864 and Haydu.

Applicants respectfully submit that this is an insufficient factual basis for the Examiner's conclusion of obviousness of the claimed invention.

The Examiner has failed to show any motivation for lifting the 2-mercaptobenzimidazole from the context of its disclosure in McCoy, in which it is used only with a trace amount of a metal and an aldehyde compound in a highly caustic electrodeposition bath, for a totally different use in a much lower pH immersion plating process such as that claimed.

The Examiner's position fails to take account of the fact that the chemistry of electroplating and that of immersion plating is totally different, despite the fortuitous "suggestion" by Heiman that his particular bath could be used for either immersion plating or electroplating, which the Examiner has bootstrapped into a license to use in an immersion plating bath virtually any chemical that might ever possibly be used in any electroplating bath. This is simply unsupportable and stretches the teaching of Heiman far beyond its reasonable applicability. This is simply insufficient basis upon which to reject Applicants' claims.

Knowledge in the Metal Treatment and Plating Art

The Examiner has repeatedly distinguished Applicants statements of fact and arguments on the basis that no factual evidence was provided in support. While some of Applicants statements are so well known and accepted that no one finds it necessary to take up space in a text or treatise to repeat them, Applicants submit evidence that shows that it would not have been obvious to select any particular electroplating brightener for use in any other electroplating system, much less for use in an immersion plating system.

It is well and broadly known in the metal treatment and plating art that both electroplating and immersion plating are *arts* and that just because a given additive

works in one, there is no reason to believe or to expect that the same additive would work in the other. In other words, there can be no reasonable expectation of success in virtually any novel combination of additive chemicals in the plating arts. The only way to determine what *will* work is to do extensive testing to determine what *does* work. This is not the sort of predictability required for the reasonable expectation of success necessary to support an obviousness rejection. While there might be motivation to try a variety of agents, this is not the sort of motivation required to support an obviousness rejection, it is nothing more than "obvious to try."

Applicants submit herewith excerpts from two treatises in the electroplating arts, both of which explicitly state that the selection of any brightener, even for use in electroplating, is empirical. That is, as stated by these treatises, the selection of any brightener is a matter of trial and error, i.e., empiricism.

Therefore, logically, if the selection of any brightener only for use in electroplating is a highly empirical, trial and error matter, then there can be no possible logical basis for the contention that it would have been obvious to use any particular brightener, known only for use in a highly specialized electroplating bath, in the totally different chemistry of immersion plating, in a novel combination for brightening, much less for a special purpose different from brightening, as here. Applicants respectfully submit that this evidence fully rebuts the Examiner's position regarding the alleged obviousness of Applicants' claimed invention.

In E. Raub and K. Müller, *Fundamentals of Metal Deposition*, Elsevier, 1967, at pages 105-106, the authors state:

Although the deposition of bright metal coatings has made enormous progress since then, the chemical and energetic processes involved in it have not yet been fully elucidated. *The development of brightening additives and brightening electrolytes has been carried out on an empirical basis.* The large number and diversity of the brightening additives makes it difficult to establish the scientific principles involved, although some steps in this direction have been made. (Emphasis added.)

Copies of these pages and the title and bibliographic pages are submitted herewith. Lest the Examiner contend that the "some steps in this direction" have rendered obsolete the statements made in 1967 by Raub and Müller, Applicants submit herewith

a more recent publication which clearly shows that any such steps have not made brightener selection, even for electrodeposition, into a predictable matter.

In N. Kanani, *Electroplating - Basic Principles, Processes and Practice*, Elsevier, 2004, at page 63, the author states:

Thus, highly reflective deposits are found under conditions where fine-grained deposits are formed. to achieve this, it is long-established practice to add metallic or organic compounds, known as brighteners or brightening agents. *Their use is based on empiricism, there being no certain means of predicting their effects. In the same way, selecting the most appropriate such compound(s) will usually be based on trial and error.* (Emphasis added.)

Copies of this page, together with the title and bibliographic pages, are submitted herewith. By way of full disclosure, it is noted that the author of this book apparently is associated with the assignee of the present application, Atotech Deutschland GmbH, although this author has nothing to do with the present invention or application.

As shown by the foregoing publications, the selection of brighteners, even for use in electroplating alone, is an empirical undertaking and requires trial and error to determine the most appropriate brightener for any given electroplating bath.

Given the many and well-known differences between electroplating and immersion plating, there is simply no factual basis whatsoever for the contention that it would be obvious to use any particular electroplating brightener in any immersion plating system.

Examiner's Response to Applicants' Arguments and Mr. Joshi's Declaration

In responding to Applicants' arguments and to the Declaration of Mr. Joshi, the Examiner summarily and in conclusory fashion stated that Mr. Joshi's sworn testimony was "in the form of opinion evidence". This is incorrect and, Applicants respectfully submit, is an improper characterization of the nature of the sworn testimony contained in the Declaration. This is so because (1) Mr. Joshi is quite obviously a person of skill in the art, (2) many of the most important statements made in Mr. Joshi's Declaration are statements of fact, not statements of opinion, and (3) Mr. Joshi made these factual statements in sworn testimony subject to the provisions noted in the final paragraph.

Despite this, the Examiner, out of hand, dismissed Mr. Joshi's statements of fact as opinion testimony unsupported by factual evidence.

Paragraphs (1)-(5) are clearly statements of fact. These include statements of the knowledge of persons of skill in the art. While (6) does contain some opinion, it is well based in fact. That the Examiner was able to find a single reference teaching the use of a brightener in a different zincating process does not change the facts and logic of the statements and conclusions in (6). Paragraph (7) is intended to rebut the Examiner's own statement of opinion, i.e., that it would have been obvious to combine Heiman and Eckles. Paragraphs (8)-(10) are also clearly factual in nature. The discussions in (11)-(13) are primarily factual, although possibly some statements might be considered opinion. (14) is opinion. Thus, while there is some opinion, there is a substantial quantity of factual information in Mr. Joshi's Declaration, which clearly rebuts the uses to which the Examiner has attempted to put the cited references in rejecting Applicants' claims.

In response to Mr. Joshi's statements, the Examiner has attempted to use the isolated disclosures of the references to rebut Mr. Joshi's statements of fact, many of which relate to the art in general, and to reasons why a person skilled in the art would not expect that any particular electroplating brightener would be useful in any immersion plating, or in any particular immersion plating system. Applicants respectfully submit that the isolated disclosures relied upon by the Examiner cannot rebut the broad understanding of those of skill in the art, as shown by both Mr. Joshi's Declaration and by the excerpts submitted herewith. Applicants respectfully submit further that the isolated disclosures relied upon by the Examiner fail to provide a sound basis for rejecting the presently pending claims and thereby denying Applicants' right to a patent on the claimed invention.

At Best, the Cited References Might Create an "Obvious to Try" Scenario

Applicants respectfully submit, therefore, based on the foregoing, and on Mr. Joshi's Declaration, at the very best there *might be* an "obvious to try" situation regarding selection of particular chemicals for use in the plating arts. That is, one might find it obvious to assemble and then try out, on an empirical, trial-and-error basis, a long list of possible additives, one at a time, that may be useful in one type of plating, when exploring and experimenting in another area of plating. But this is not a suggestion.

This is not a motivation. This is not and does not create a reasonable expectation of success. This is nothing more than an "obvious to try" scenario.

And, as the Examiner is likely well aware, "obvious to try" does not beget obviousness, "obvious to try" is not obviousness, and "obvious to try" is not the standard for use in an obviousness analysis.

Accordingly, Applicants respectfully submit that the presently claimed invention would not have been obvious over the contended combinations of references.

Applicants' Summary of Substance of Examiner Interview

On 22 February 2007, Applicants' undersigned attorney and Examiner Bareford conducted a personal interview in the Examiner's office. Applicants and Applicants' undersigned attorney wish to thank the Examiner for the courteous and helpful comments and discussion in the interview.

In the interview, the prior art discussed in the present Reply was discussed. Various differences between the use of the mercapto compounds of McCoy as compared to the then-pending claims was discussed. In addition, possible experimental results were discussed. Applicants' attorney pointed out that the brighteners used by Haydu are polymers, and that Applicants' brighteners are monomers.

No agreement was reached between the Examiner and Applicants' attorney.

A copy of the Exhibit A inadvertently omitted from the Declaration of Nayan Joshi was provided to the Examiner at the interview.

The foregoing constitutes the summary of the substance of the Examiner interview, in accordance with the MPEP and 37 CFR § 1.133.

Conclusion

In view of the amendments to the claims and the foregoing remarks, it is respectfully submitted that all of the claims presently in the application fully patentably distinguish over the prior art and are in condition for allowance. Notice to such effect is respectfully requested.

In the event issues arise as a result of the filing of this paper, or remain in the prosecution of this application, Applicants request that the Examiner telephone the undersigned attorney to expedite allowance of the application.

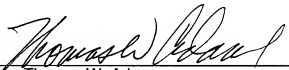
Should a Petition for Extension of Time be necessary for the present Reply to the outstanding Office action to be timely filed (or if such a petition has been made and an additional extension is necessary) petition therefor is hereby made and, if any additional fees are required for the filing of this paper, the Commissioner is authorized to charge those fees to Deposit Account #18-0988, Docket No. ATOTP0104US.

Respectfully submitted,

RENNER, OTTO, BOISSELLE & SKLAR, LLP

Date: April 4, 2007

By



Thomas W. Adams
Reg. No. 35,047

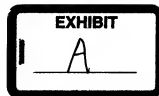
1621 Euclid Avenue
Nineteenth Floor
Cleveland, Ohio 44115
(216) 621-1113

C:\MY FILES\ATOT\ATOT104\ATOTP0104US amd 7.wpd

Nayan H. Joshi

Publications and Patents

1. "Effect of Some Dyes on the Corrosion of Aluminium in Potassium Hydroxide", *Denki Kagaku*, 45, 716 (1977).
2. "Aldehydes as Corrosion Inhibitors for Aluminium-Magnesium Alloys in Potassium Hydroxide", *Workstoffe Und Korrosion*, 29, 461 (1978).
3. "Some Aromatic Hydroxy-compounds as Corrosion Inhibitors for Aluminium-Copper Alloy in Sodium Hydroxide", *Proceedings of 7th International Congress on metallic Corrosion, Rio de Janeiro, 1979, p. 1878 Abraco, Rio de Janeiro, Brazil.*
4. Corrosion of 3S Aluminium by Mixture of Alkalies and its Inhibition by Oxo-anions", *Workstoffe Und Korrosion*, 31, 290 (1980).
5. "Some Dyes as Corrosion Inhibitors for 3S Aluminium in Potassium Hydroxide", *Korrosios Figyelo*, 20, 3 (1980).
6. "Corrosion of Aluminium in Aliphatic Amine and its inhibition by Some Dyes", *Workstoffe Und Korrosion*, 31, 926, (1980).
7. "Furfuraldehyde and Salicylaldehyde as Corrosion Inhibitor for 3S Aluminium in Sodium Hydroxide", *J. Electrochem. Soc. of India*, 30, 253, (1981).
(1981-MASCOT Award winning paper in Corrosion Science)
8. "Self-accelerating & Replenishing Non-formaldehyde Immersion Copper", *U.S. Patent # 5,543,182*.
9. "EMI-RFI Shielding with Direct Plating Technology", *paper presented at Surfin '96, Cleveland, Ohio.*
10. "Composition and Process for Treating a Surface Coated with a Self-accelerating and Replenishing Non-formaldehyde Immersion Coating", *U.S. Patent # 5,725,640*.
11. "Verfahren zum selektiven oder partiellen elektrolytischen Metallisieren von Substraten aus nichtleitenden Materialien", *German Patent # DE 195 10 855 C 2*.
12. "Metallization of Non-conductive Surfaces with Silver Catalyst and Electroless Metal compositions", *US patent #6,645,557 B2*.
13. "Aqueous Alkaline Zincate Solutions and Methods", *US Patent #6,790,265 B2*.
14. "Aqueous Alkaline Zincate Solutions and Methods", *US Patent #6,811,819 B2*.



15. "Nitric Acid and Chromic Acid free Compositions and Process for Cleaning Aluminum and Aluminum Alloys", *Applied for patent – Pub. No. US 2004/0242449 A1, Dec.2, 2004.*
16. "Aqueous Acidic Immersion Plating Solutions and methods for Plating on Aluminum and Aluminum Alloys", *Applied for Patent – Pub. No. US 2005/0008788 A1, Jan. 13, 2005.*

*Fundamentals
of
Metal Deposition*

by

E. RAUB AND K. MÜLLER

Schwäbisch Gmünd, Germany

ELSEVIER PUBLISHING COMPANY

AMSTERDAM - LONDON - NEW YORK

1967

Organic additions are particularly widespread. However, not the additives but their decomposition products are often codeposited²⁰⁷. Elucidation of the deposition mechanism is thus difficult and relatively few studies have been carried out.

The incorporation of these foreign substances is of special importance for the technological properties—this will be dealt with in greater detail when the various properties are discussed (Table 8).

Prall and Schreit^{142a} were able to prove that copper deposited from a benzotriazole-containing sulfate electrolyte incorporates undecomposed benzotriazole in the form of the sparingly soluble stable complex with copper(I) ions. By means of a suitable analytical method, the benzotriazole was recovered from the copper and determined quantitatively. In this manner it was also possible to study benzotriazole incorporation as a function of electrolyte composition and other deposition conditions.

The chemical properties of electrodeposited coatings are also clearly affected by incorporation of foreign substances¹⁶⁷. Thus, a measurable difference in the equilibrium rest potential as compared with that of the pure metal can often be found. The metal containing foreign substances usually has the less noble potential. The tarnishing rate is often increased, and chemical reagents also attack the metal more vigorously. Thus, for example, the induction period for the attack of dilute nitric acid on silver is shortened and sometimes reduced to zero¹⁸². On the other hand, the lower corrosion resistance of bright nickel as compared with mat nickel is not due to the general effect of the foreign incorporations in bright nickel coatings, but to the specific effect of their sulfur content.

3.10 Deposition of bright metals

The production of bright metal deposits is a relatively young branch of electroplating technology. The development of brightening electrolytes, which is credited to M. Schlötter²⁰⁹, began around 1930, when bright nickel coatings could for the first time be produced by adding organic compounds to simple nickel electrolytes. Although the deposition of bright metal coatings has made enormous progress since then, the chemical and energetic processes involved in it have not yet been fully elucidated. The development of brightening additives and brightening electrolytes has been carried out on an empirical basis. The large number and diversity of the

Organic additions are particularly widespread. However, not the additives but their decomposition products are often codeposited²⁰⁷. Elucidation of the deposition mechanism is thus difficult and relatively few studies have been carried out.

The incorporation of these foreign substances is of special importance for the technological properties—this will be dealt with in greater detail when the various properties are discussed (Table 8).

Prall and Schreir^{142b} were able to prove that copper deposited from a benzotriazole-containing sulfate electrolyte incorporates undecomposed benzotriazole in the form of the sparingly soluble stable complex with copper(I) ions. By means of a suitable analytical method, the benzotriazole was recovered from the copper and determined quantitatively. In this manner it was also possible to study benzotriazole incorporation as a function of electrolyte composition and other deposition conditions.

The chemical properties of electrodeposited coatings are also clearly affected by incorporation of foreign substances¹⁶⁷. Thus, a measurable difference in the equilibrium rest potential as compared with that of the pure metal can often be found. The metal containing foreign substances usually has the less noble potential. The tarnishing rate is often increased, and chemical reagents also attack the metal more vigorously. Thus, for example, the induction period for the attack of dilute nitric acid on silver is shortened and sometimes reduced to zero¹⁵². On the other hand, the lower corrosion resistance of bright nickel as compared with mat nickel is not due to the general effect of the foreign incorporations in bright nickel coatings, but to the specific effect of their sulfur content.

3.10 Deposition of bright metals

The production of bright metal deposits is a relatively young branch of electroplating technology. The development of brightening electrolytes, which is credited to M. Schlötter²⁰⁹, began around 1930, when bright nickel coatings could for the first time be produced by adding organic compounds to simple nickel electrolytes. Although the deposition of bright metal coatings has made enormous progress since then, the chemical and energetic processes involved in it have not yet been fully elucidated. The development of brightening additives and brightening electrolytes has been carried out on an empirical basis. The large number and diversity of the

brightening additives makes it difficult to establish the scientific principles involved¹⁹⁷ although some steps in this direction have been made (*cf.* p. 118).

Agreement has not yet been reached concerning the definition and correct measurement of brightness²¹³. This is due to the fact that a bright appearance is not a physical property of a material.

It seemed logical to equate brightness with mirror reflection and to measure brightness by the reflectance. It was found, however, that the results thus obtained are inadequate for characterizing unequivocally the property perceived by the human eye as brightness. A stronger impression of brightness does not necessarily correspond to a higher intensity of the mirror-reflected light. R. Springer²¹⁸ recommends the use of the word "brightness" merely in the sense of the original linguistic usage to designate the psychophysical sensation and to designate physical brightness by the term "mirror reflectance".

With regard to the reflection of light at a surface, three possibilities must be distinguished. When light is reflected diffusely, the surface has a mat appearance. When all light is reflected directionally, the surface has a mirror appearance. If, however, most of the light is reflected directionally and only a small proportion of it diffusely, *i.e.*, if the reflection is only partially directional, the surface appears bright. From this point of view it appears more logical to determine the psychophysical impression of brightness by measuring the diffusely reflected instead of the mirror-reflected light.

When the nature of the surface (which determines brightness) is studied under the optical or electron microscope, only a small part of it is viewed at one time, while the human eye evaluates the entire surface. A surface which is termed smooth in common linguistic usage generally has a roughness of the order of microns. This is responsible for the diffuse reflection. The proportion of diffusely reflected light decreases when the micro-roughness is reduced on average to at least below the length of the shortest wavelength of light, which is 0.4μ . Hence, during electrolytic deposition of bright metal coatings, crystallization must be controlled in such a manner that this microroughness of the surface is removed. The presence of macroroughness with a magnitude considerably above the wavelength of light does not interfere with the brightness of a coating.

The control of crystallization required for the deposition of bright metal coatings is achieved by means of brightening additives. Their effect arises from the fact that they or their reduction and decomposition products are adsorbed on the cathode surface. This adsorption may take place prefer-

216 621 6169

Electroplating – Basic Principles, Processes and Practice

Nasser Kanani
Atotech Deutschland GmbH,
Berlin, Germany

C 2004

Prof.

**ELSEVIER**

UK Elsevier Ltd, The Boulevard, Langford Lane, Kidlington, Oxford OX5 1GB, UK
USA Elsevier Inc, 360 Park Avenue South, New York, NY 10010-1710, USA
JAPAN Elsevier Japan, Tsuoshima Building Annex, 3-20-12 Yushima, Bunkyo-ku, Tokyo 113, Japan

Copyright © 2004 Prof Dr Nasser Kanani. Published by Elsevier Ltd.

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system or transmitted in any form or by any means: electronic, electrostatic, magnetic tape, mechanical, photocopying, recording or otherwise, without permission in writing from the publishers.

British Library Cataloguing in Publication Data

Kanani, Nasser

Electroplating: basic principles, processes and practice

1. Electroplating

I. Title

671.732

ISBN 1856174514

No responsibility is assumed by the Publisher for any injury and/or damage to persons or property as a matter of products liability, negligence or otherwise, or from any use or operation of any methods, products, instructions or ideas contained in the material herein.

Published by

Elsevier Advanced Technology

The Boulevard, Langford Lane, Kidlington, Oxford OX5 1GB, UK

Tel: +44(0) 1865 843000

Fax: +44(0) 1865 843971

Typeset by Newgen Imaging Systems (P) Ltd., Chennai, India

Working together to grow
libraries in developing countries

www.elsevier.com | www.bookaid.org | www.sabrc.org

ELSEVIER

BOOK AID
International

Sabre Foundation

deposit thickness distribution. These systems are usually operated at 18–35°C and at a deposition current density of 0.5–6 A/dm² [9].

3.2.1.4 Electrolyte additives

In addition to metal salts, electrodeposition electrolytes usually contain various other species. Thus both inorganic and organic salts, acids or alkalis will be added to increase electrolyte conductivity. Other species, both organic or inorganic, may be added for specific purposes, for example, to increase bath stability, or improve levelling or metal distribution, or to optimise the chemical, physical or technological properties of the deposited metal (corrosion resistance, brightness or reflectivity, hardness, mechanical strength, ductility, internal stress, wear-resistance or solderability).

In working with such additives, it should be recognised that they are often effective over only a defined concentration range, and should their concentrations fall outside this range, all kinds of problem can arise either in the deposition process or the deposit properties. In the following sections, such addition agents are considered in greater detail.

3.2.1.4.1 Brightening agents

In metal finishing, bright or highly reflective surfaces (the terms are usually synonymous) can be of both decorative and functional importance, if for no other reason than that bright surfaces require less mechanical finishing, after plating, if indeed any at all.

Defining brightness or reflectivity of a surface as the extent to which incident light is reflected, it follows that surface roughness and unevenness are antithetical to good reflectance. Reflective surfaces are characterised by a crystallite size at the surface of less than 0.3 μm^2 . Thus, highly reflective deposits are found under conditions where fine-grained deposits are formed. To achieve this, it is long-established practice to add metallic or organic compounds, known as brighteners or brightening agents. Their use is based on empiricism, there being no certain means of predicting their effects.

In the same way, selecting the most appropriate such compound(s) will usually be based on trial-and-error.

Two different types of brightener are recognised, the first being brightener carriers, the second, brightener additives [10–12].

Addition of brightener carriers, also known as primary brighteners or Class I brighteners, leads to a significant grain refining action in the deposited metal. While this greatly increases the brightness of the metal, it will not impart a mirror-finish or anything close to this. Among the best-known brighteners of this type are [13]

- sulfonamides
- sulfonimides
- benzenesulfonic acids (mono-, di- or trisulfonic acids)
- naphthalenesulfonic acids (mono-, di- or trisulfonic acids)
- alkylsulfonic acids
- sulfinic acids
- arylsulfonesulfonates.

These primary brighteners are essential components of a complete brightening system, in that they reinforce the efficacy of Class II or secondary brighteners, the